Fedia radiata Michx., var. *umbilicata* (*F. umbilicata* Sulliv.). Fig. 108. Fruit (from Columbus, Ohio); *a*, side view; *b*, another side view, showing the cruciform opening caused by the tendency of the cell in the abnormal expansion of its walls to split along the sutures; *c*, cross section of the same; *d*, side view of a more mature fruit, showing a further enlargement of the opening into the empty cell; *e*, another side view. As the fruit of the former variety came probably from that of *F. radiata*, with two empty cells, as seen in Fig. 104 *b*, so this may have been derived, by the operation of the same cause, from that of Fig. 104 *c*, with the empty cells confluent.

In view of the decided disposition toward monstrosity evident in Fig. 107, and the differences of the fruits in size and shape, it is questionable whether *F. patellaria* and *umbilicata* are worthy to stand even as varieties of *F. radiata;* but, since no typical fruits of the latter have been observed intermingled with the aberrant forms on the same stalk, they may for the present be recognized as such.

MIMICRY IN THE COLORS OF INSECTS.

BY DR. H. HAGEN.

Having observed that in treating of the interesting phenomena of mimicry, writers have used indiscriminately very different factors, I shall try to give some preliminary ideas which I do not find published, and which I believe will be useful in explaining this interesting subject.

It will be best to consider the color and pattern separately. There are three different kinds of colors: viz., colors produced by interference of light, colors of the epidermis, and colors of the hypodermis. All three may either be wanting, or all three, or two of them may occur together in the same place.

Colors produced by interference are produced in two different ways; first by thin superposed lamellæ, as in the wings of Diptera, Neuroptera, etc., without any other color, as in hyaline wings, or connected with other colors as in the scales of Entimus and others.

There must be at least two superposed lamellæ to bring out

colors by interference, and there cannot be more than four, as both wings and scales consist only of four layers, two internal belonging to the hypodermis, two external belonging to the epidermis. In fact, if scales taken from dry specimens of Entimus are observed under the microscope, many partly injured can be found, which give different colors according to the layers of the lamellæ which remain.

Secondly, colors by interference are produced by many very fine lines or striæ in very near juxtaposition, as in Apatura and other color-changing insects. Colors by interference may perhaps be sometimes also produced in the same way as in the feathers of the dove's neck by very small impressions situated near together.

The colors produced by the interference of light are only optical phenomena, differing in this respect from the other colors of the body, the epidermal and hypodermal colors.

The epidermal colors belong to the pigment deposited in the cells of the chitinized external skin, the epidermis. These colors are mostly metallic blue, green, bronze, golden, silver, black, brown, and perhaps more rarely red. The epidermal colors are very easily recognized, because they are persistent, never becoming obliterated or changed after death.

The hypodermal colors are situated in the non-chitinized and soft layer, called hypodermis by Weismann. They are mostly brighter and lighter, light blue or green, yellow, milk white, orange and all the shades between. The hypodermal colors *in the body* of the insect fade or change, or are obliterated after the death of the insect. A fresh or living insect when opened may easily be deprived of the hypodermal colors simply by the action of a little brush. I said hypodermal colors in the body, because there are hypodermal colors which are better protected, being encased nearly air-tight, and therefore are more easily preserved even after the death of the insect. I refer to the colors in the elytra and wings, and in their appendages, the scales. The elytra and the wings are, as is well known, at first open sacs in communication with the body, of which they are only the extension: of course they are formed of the epidermis and hypodermis which become so strongly glued together after the transformation into the imago state that a maceration of years tried by me showed no effect at all on such wings. This fact is very interesting as it explains how wings, and even colored wings, can be found in palæontological

layers in good preservation. The destruction of insects, which is so peculiar to the secondary strata in England, proves, as I believe, that the bodies of the insects must have floated a very long time before they were deposited. It is quite a rarity to find well preserved insects there although many very well preserved wings even of lace-winged flies have been described.

There is an interval after the transformation before the membranes of the wings become inseparably glued together; it is at this time that the finishing of the colors takes place. For instance in an Æschna, a *Libellula depressa* or *trimaculata*, if the wing is cut off at the base, the two layers can be easily separated by manipulation under water, and the wing can be inflated with a little tube by separating the borders with a knife. I can show specimens so prepared. But this is only possible as long as the wings possess the appearance of having been dipped into mucilage, an appearance which is well known in young Odonata.

The scales have just the same development as the wings. At first they are little open sacs, communicating with the hollow of the wing and the whole body, and at a later period are glued together like the wings themselves.

In the wings and in the scales the hypodermal colors are formed and finished before the wings stick together, and by this means they are well preserved and safely encased. They have no more communication in the glued parts with the interior of the animal, and are preserved in the same way, as if hermetically inclosed in a glass tube. There are even here in the wings and scales many epidermal colors, chiefly the metallic ones; but all the brighter colors (for instance the somewhat transparent spots in the elytra of the Lampyridæ, Cicindelidæ, etc., and in the greater number of Lepidoptera) are, as I believe, hypodermal colors.

Finally there sometimes occurs outside of the animal, that is, on the epidermis, a kind of color which I consider as hypodermal color, such as the pale blue on the abdomen of many Odonata, the white on the outside of many Hemiptera, the pale gray on the elytra and thorax of the Goliathus beetle, the powder on Lixus and others. Some of these colors are very easily resolved in ether, and are apparently a kind of wax. I believe that these colors are produced by the hypodermis and are exuded through the little channels of the pores (*Poren Canæle*).

The hypodermal colors are very often different in males and

females of the same species, the epidermal colors rarely differ so far as I know; but there are genera with prominent epidermal colors which are nearly always different in different sexes, viz., Calopteryx, Lestes, some Hymenoptera, etc.

It would be interesting to know the different colors of the epidermis in such cases. So far as I know the change seems to be between related and not between complementary colors. But my observations are far from having any conclusive importance. The same investigation would be necessary for the hypodermal colors.

The hypodermal colors may change or be altered in some way in a male or female during its lifetime, by sexual or other influences. The epidermal colors never change. By sexual influences yellow is changed into orange, brown into red, and even sometimes more changed. By other influences, for instance by cold in hibernation, pale yellow is changed into red (Chrysopa). The hypodermal colors can be changed even by a voluntary act of the animal, and the new colors disappear again (Cassida). The hypodermal colors are the only ones on which the animal has any influence either involuntarily by the action of the nutritive fluid or voluntarily. The epidermal cells are placed entirely outside of any influences of the animal, when once established. It will perperhaps be possible to prove that the so-called mimetic colors are all hypodermal colors.

The hypodermal colors seem to be produced by a photographic process (I know no better expression), the epidermal colors by a chemical process of combustion or oxidation. Would it be possible to prove that by a photographic process even the colors of the surrounding world could be transmitted, a great step towards an undertaking of the phenomena would be given. The fact of course is very probable, at least in some instances.

In observing the mimicry, the pattern of an insect must be clearly separated from the color. In fact the pattern is not the product of an accidental circumstance, but apparently the product of a certain law, or rather the consequence of certain actions or events in the interior of the animal and in its development. The proof is very easily afforded by the regularity of the pattern in a genus, or a family of insects. If studied carefully and comparatively the pattern in a genus is the same or is only more or less elaborated. The number of such families is so exceedingly great that some example will readily occur to every one.

Moreover a certain and constant pattern can be found for the head, a different pattern for the segments of the thorax, and a different pattern for the segments of the abdomen. This pattern is in the different segments of the abdomen (Hymenoptera, Diptera, Neuroptera, Orthoptera) always the same, only more or less elaborated, and less finished in the first and last segments. In some way the same is true for the thoracic segments.

In some few instances I was able to observe how the pattern is produced. In the Odonata (Dragon flies) at the moment of transformation the thorax is transparent, and shows no colors at all. At this time the muscles are without importance and in process of formation. The thoracic muscles as is well known are, in the Odonata, very powerful, and also very extraordinary as regards the shape of their tendons. Just along outside the muscles are dark lines more or less well finished, and resulting from the action of the muscles. *Ubi irritatio, ibi affluxus.* I believe that it would not be unphilosophical to conclude that a powerful action in the development of the muscles is in such a case the cause of a greater combustion or oxidation in the neighboring parts. In fact on the head of a Cicada, on the abdomen of an Æschna we find similar patterns, in some way mostly representing the underlying muscles. In the Gomphina the fact is striking and far more as the stronger species mostly possess a larger dark pattern. There are some very small species which are almost entirely yellow; there are no small species entirely black.

Should the fact, with the explanation, be admitted, a step farther in the explanation of the different patterns would be made. I know very well that in the Odonata there are patterns which do not agree with my explanations, even some contrary to it, but if some certain facts be explained, there are perhaps more factors still unknown or unobserved. The explanation given for certain facts would still be admissible, or at least not entirely objectionable.*

---

*So far as I know the literature relating to the phenomena of mimicry, all these related differences are often confused, and I believe that in separating them and following the views above given, many facts would be better understood and this interesting subject more easily advanced.

Besides all the difficulties which oppose a clear and correct view, there is one more which I do not find mentioned, *i. e.* the so called color-blindness and the different degrees of it. Prof. B. A. Gould in his excellent work "Investigations on Anthropological Statistics of American Soldiers" has given attention to it in a very remarkable chapter. Persons who cannot distinguish ripe cherries upon the tree, or strawberries

The patterns on the wings and elytra could not be the product of the action of muscles, but I believe it to be probable that the sudden rush of blood or even air, by the accelerated circulation and respiration in the act of transformation may have the same effect. In this way some patterns, otherwise not explicable, could be understood. The eyespots in the caterpillars of some Papilionidæ have been ascertained by Leydig to be epidermal colors, and I believe that the various kinds of eyespots in the wings of the imago are also epidermal colors. If a stream of blood meets a small obstacle just in the centre, a funnel is formed; if this obstacle is a ring, and behind it another obstacle we have two or more funnels, one in the other, and the section of them will be circular or elliptical according to the angle at which they reach the surfaces. Such patterns in the elytra and wings are formed or preformed at the time when the wing is a sac; sometimes before the transformation, and here is another circumstance which explains some patterns. The walls of the sac are suddenly augmented and strongly dilated in the transformation. Small patterns preformed in the sac will also be altered and enlarged by the same process, and I know that many patterns of Lepidopterous wings are in such a way very easily explained. All the waved lines of the wings and other marks belong here, and as the ribs or nervures seem to grow faster in transformation, the waved appearance would be explained. In fact the greater part of the patterns seem to be produced by expansions or distraction of the pattern preformed in the wing at some period before the transformation.

---

on the vine by their color are far more numerous than would be suspected. Serious misunderstandings and even calamities have been reported in the army, resulting from mistakes in the color of green and red light by officers of the signal corps." He gives the statement that usually one in twenty, and in the soldiers examined one in fifty was subjected to color-blindness. But these numbers show only the extremes and it is easy to believe that a much greater number are more or less affected with it. In fact we have no means of measuring this physiological difference; if two persons call something green, and even compare the color with certain known objects there is no proof at all that they see just the same color. I think that it would be prudent in describing cases of mimicry, especially when they are extraordinary, not to forget that even the best observer may be unaware of this infirmity, and in fact the best authorities on color-blindness always state that the greater number of persons have no idea of their infirmity.